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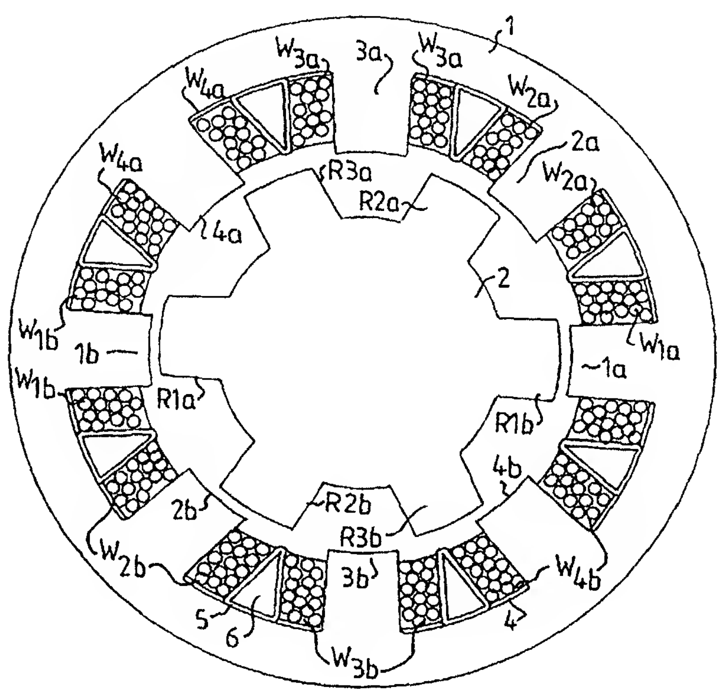
(54) Title: COOLING SYSTEM FOR AN ELECTRICAL MACHINE

(57) Abstract

The invention relates to a cooling system for an electrical machine having windings (W1a, W2a, W3a, W4a) provided in internal grooves with conductors collected in proximate relation. Casting compound (4) around the conductors in the windings in each groove of a material having good thermal conducting performances. At least one tubular channel (5) is provided in close proximity of a portion of the casting around the windings and a cooling fluid (6) flows in said channels (5).



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Cooling system for an electrical machine

This invention relates to a cooling system for an electrical machine comprising a winding-carrying stator of the kind disclosed in the preamble of claim 1.

BACKGROUND OF THE INVENTION

Normally, the maximum power drain in all kinds of electrical machines is limited by the upper temperature limit for which the copper conductors are manufactured. There are a number of norm classes for copper conductors, such as class F (155 °C), Class H (180 °C) etc. For a given power drain, the temperature rise in the copper conductors depends on the thermal conductivity to the surrounding material - usually to the iron core, on which the copper conductors are positioned. The thermal energy is normally transported from the copper conductors to the iron core and further to the engine house which keeps the core in place. The amount of heat energy which can be removed depends upon the kind of cooling to be used (for example convection, thermal conduction, thermal radiation) and how an air/liquid flow is directed around and/or through the engine. Liquid/oil cooling is commonly used in machines or engines having a requirement for large thermal discharges.

DESCRIPTION OF RELATED ART

The US patent No 5,489,810 discloses a switched reluctance machine having cooling channels inside the current conductors in the windings wound on a plurality of the salient stator poles. This a very efficient way of cooling away the thermal energy from the conductors, however it is

also very expensive. The windings of two adjacent poles are separated by a triangular base separator.

The US patent No 5,578,879 shows in an embodiment (FIG 2) that cooling fluid flows through channels positioned adjacent to two salient stator windings in an electric machine and thus cools both the stator windings and the stator pole parts. A cover is placed between the stator and the rotor to hold the fluid in the channels. The cooling channels are here positioned on the side of the windings facing the rotor. This means that the position of the cooling channel has an influence on the dimensioning of the electrical windings and the stator poles which is disadvantageous.

OBJECTS OF THE INVENTION

An object of the invention is to lower the temperature in the electrical copper conductors in an engine having a winding-carrying stator, for example a switched varying reluctance machine, by transporting away, in an effective way, the vaste heat produced in the stator windings when they conduct an electric current which heats them up.

Another object of the invention is to transport the thermal energy away from the stator windings in an electric machine in, for example, a varying reluctance machine or a DC machine having a permanent magnetic field in an effective but still economical way.

SUMMARY OF THE INVENTION

The above stated objects are obtained by a system which has the characteristics stated in claim 1. Further features and developments of the invention are stated in the rest of the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and for further objects and advantages thereof, reference is now made to the following description of examples of embodiments thereof - as shown in the accompanying drawing, in which:

FIG. 1 shows an embodiment of a stator and a rotor of a variable reluctance machine in a sectional view;

FIG. 2 shows a side view of a motor and a first embodiment of the cooling system outside the motor; and

FIG. 3 shows a side view of a motor and a second embodiment of the cooling system outside the motor.

The description of the embodiment shown in FIG. 1 is based on the kind of switched reluctance motor described in the article "Inverter drive for switched reluctance motor: circuits and component ratings" by R.M Davis et al, IEE PROC, vol. 128, Pt. B, No. ", March 1981, pages 126 to136, and illustrated schematically on page 126 in this article. However, the invention could also be adapted to permanent magnet machines or hybrid machines having stators with adjacent pole windings, and to other machines in which relatively large windings are used and where a lot of copper conductors are collected in a proximate relation (thus not spread out). The poles of both the stator and the rotor could be teethed in different ways as known from the prior art, as shown for example in the US Patent No 4,748,362 by the same Assignee as for this application (the name of the company has been changed since the filing of that Application). However, such pole teething is not illustrated since it is not a part of the actual invention.

FIG. 1 shows a stator 1 and a rotor 2, both made of a soft magnetic iron material. The stator 1 has pole teeth 1a, 1b, 2a, 2b etc. on its inside protruding towards the rotor 2. The rotor 2 has teeth R1a, R1b, R2a, R2b, etc. protruding outwardly towards the stator. A winding W1a, W1b and W2a, W2b etc. is positioned around each stator pole. FIG. 1 illustrates a four phase motor having poles 1a,1b, and 2a, 2b etc. of the same kind positioned diametrically in relation to each other and having its windings switched on one after the other, thereby drawing the nearest teeth of the rotor 2 to be in front of the switched on diametrically positioned pole parts in question and in this way setting the rotor in rotation.

In order to have a very good cooling of the windings each of them is encased in a cast compound 4 having very good thermal conducting performances, for example a cast compound of epoxy resin mixed with mineral powder, for example silicon or an oxide of aluminum. An example of a suitable compound is "Avaldit CW 1302", manufactured by CIBA-GEIGY. Those materials have a good thermal conduction but have also a good electrical isolation performance.

As common in the art a base separator 5 is provided between each two neighbouring windings, for example between the windings W2b and W3b. However, and is not shown in the prior art, this base separator is here a cooling tube 5 and is made of a thermal conducting material, and is provided with at least one inside channel 6 in which a cooling fluid flows. The cooling tube could for example be provided by a cross-linked or compressed polyethylene, known as PEX.

Instead of having a cooling tube 5, the casting of the cast compound around the windings could be performed with the windings in place by using a casting mould having the sides turned to the windings shaped as

the fitting sides of the cooling tube 5. When the casting has been made the casting mould is taken away and the remaining cavity is used as a cooling channel having direct access to the thermal conducting material around the conductors in the windings. It is also possible to fill the casting compound directly in the cavity having the windings inserted and then also filling the separating space between the windings where the tube 5 should be positioned. When the casting procedure is finished channels for the cooling fluid are drilled or made in some other suitable way between the windings. In such a case it is important that the cooling fluid does not have a corrosive action on the cast compound 4, i.e. the cast compound and the cooling fluid are chosen such that they are practically chemically inert in relation to each other.

In this way the heat from the winding conductors is transmitted to the tubular base separator 5 being cooled by the cooling fluid. This can be made approximately as effective and much cheaper than the cooling system described in the US Patent No 5,489,810.

The cooling fluid 6 could be transmitted in parallel through the channels 5 as illustrated in FIG. 2, in which a closed cooling system is shown having an external combined cooler and pump 10 connected to a cooling medium distributor 11, at one end of the motor 12, which distributes the cooling medium to the channels 5 (not shown in FIG 2). The cooling element 10 could be made in many different ways well known to the person skilled in the art, and is therefore not described in detail. The important feature with respect to the present invention is just that the cooling medium is cooled and is forced to flow through the cooling tubes 5. A cooling medium joining unit 13 connected to the tubes 5 at the other end side of the motor 12 collects the fluid coming from them. The shapes of

the units 11 and 13 have to be adapted to let the rotating axis 14 of the motor pass through them and could, for example, be annular or the like.

The cooling fluid 6 could instead be transmitted in series through the channels 5 as illustrated in FIG. 3, in which a closed cooling system is shown having an external combined cooler and pump 15 connected to one of the cooling tubes 5 (not shown) at one end of the motor 12. The element 15 is connected to another of the tubes 5 at the other end of the motor 12. The tubes 5 are connected in series by means of tube pieces of tube 16 or the like.

The best result is established from the cooling fluid if a rotational flow is provided because this enhances the transfer of heat from the winding part to the cooling fluid. This could be obtained by having a sufficiently high flow rate. It is also possible to design the inlet tubes such that the flow starts to rotate before it enters a cooling tube, for example by providing it with an internal flange or the like (not shown).

The flow rate should be so high that the temperature difference between the input and the output flow is lower than a predetermined value, for example lower than 0.5 °C. This means that the flow rate for the series connection shown in FIG. 3 should be higher than in the parallel connection shown in FIG. 2, i.e. the fall of pressure from the inlet to the outlet is higher for the series connection than for the parallel connection.

As illustrated in FIG. 3, temperature sensors 17 and 18, respectively, could be provided to sense the temperatures in the inlet and in the outlet. The outputs of the sensors 17 and 18 are each connected to a different input of a differential voltage unit 19, which adjusts the pumping rate of the pump to a higher level, when the differential temperature between the

inlet and the outlet is too high. In this way the pumping rate does not have to be at a very high level all the time. A higher rate means more noise and it is advantageous if this could be avoided except when needed.

The cooling fluid could be water or oil, for example silicon oil.

We Claim

1. Cooling system for an electrical machine having windings provided in internal grooves with conductors collected in proximate relation, **characterized by**
casting compound (4) cast around the conductors in the windings (W1a, W2a, W3a, W4a) in each groove, said casting compound (4) being made of a material having good thermal conducting performances;
at least one tubular channel (5) provided in close proximity of a portion of the casting compound (4) around the windings (W1a, W2a, W3a, W4a) and in which a cooling fluid (6) is flowing.

2. Cooling system according to claim 1, **characterized** in that the tubular channel (5) is provided with walls made of a thermal conducting material.

3. Cooling system according to claim 1, **characterized** in that at least one wall of the tubular channel is provided by the casting compound (4) itself.

4. Cooling system according to claim 3, **characterized** in that the material in the casting compound (4) and the cooling fluid are inert in relation to each other.

5. Cooling system according to anyone of the preceding claims, **characterized in** that the casting compound (4) comprises epoxy resin mixed with mineral powder, for example of silicon or an oxide of aluminium.

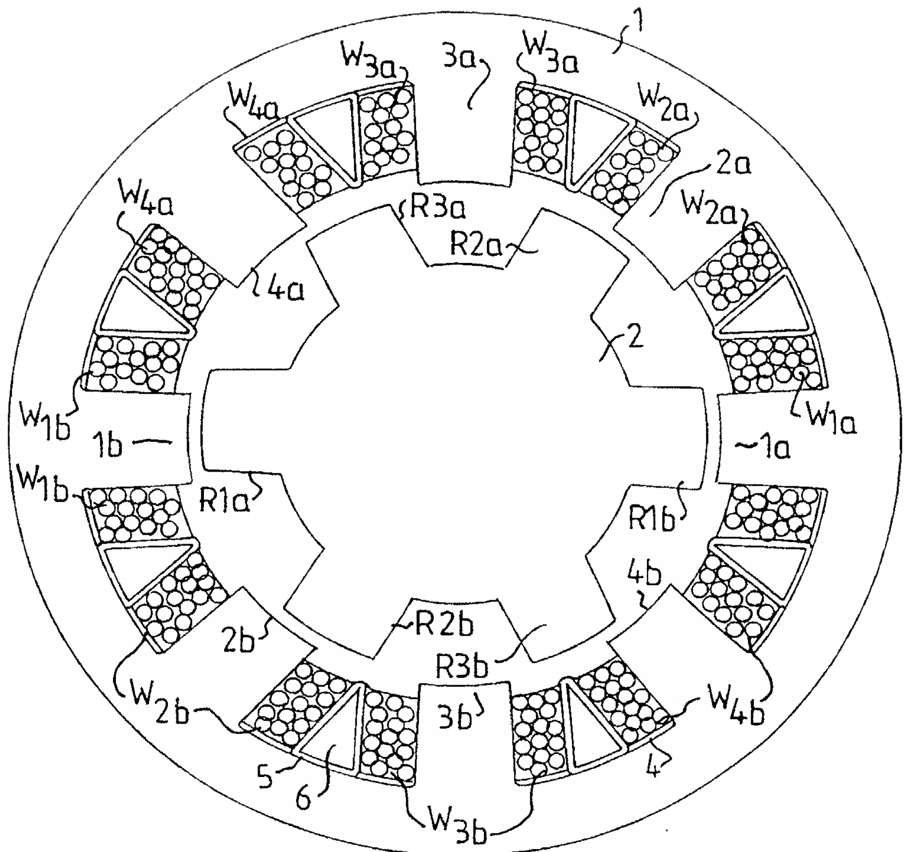
6. Cooling system according to anyone of the preceding claims for a machine having stator poles positioned adjacent to each other, **character-**

ized in that the tubular channels (5) are placed adjacent to the windings belonging to two different poles.

7. Cooling system according to claim 6, **characterized** in that all the tubular channels (5) are arranged in parallel to each other.

8. Cooling system according to claim 6, **characterized** in that all the tubular channels are arranged in series to each other.

9. Cooling system according to anyone of the claims 6 to 8, **characterized** by means (17, 18, 19) to measure the differential temperature between input fluid and output fluid through the channels, and in that the result of the measuring controls the pumping rate of a pump (10; 15) for the fluid stream.


1
3a
W3a
W3a
W2a
W4a
2a
W2a
W4a
R3a
R2a
4a
2
W1a
W1b
1b
1a
W1b
R1a
R1b
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2b
R3b
W2b
3b
W4b
4
5
6
W3b

FIG.1

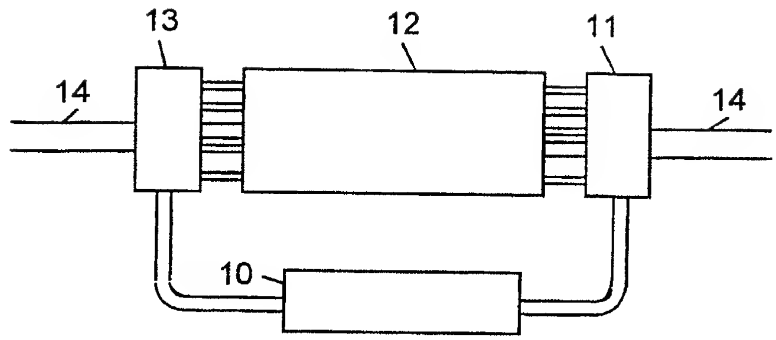

FIG 2

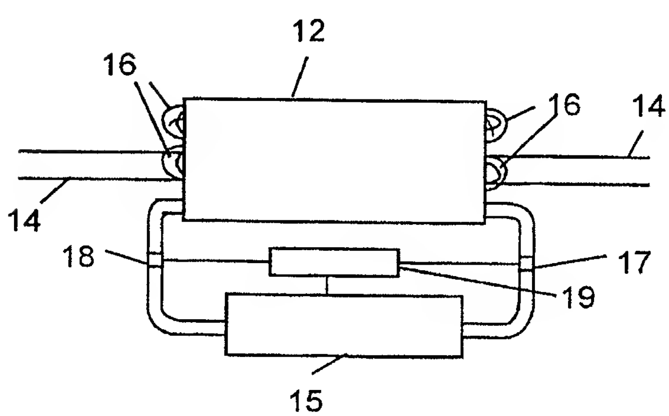

FIG 3

INTERNATION... SEARCH REPORT

International application No.
PCT/SE 99/01079

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H02K 3/24, H02K 1/20, H02K 9/22
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4644210 A (J.W. MEISNER ET AL.), 17 February 1987 (17.02.87), claims 16,17 --	1-9
A	US 5489810 A (C.A. FERREIRA ET AL.), 6 February 1996 (06.02.96), abstract --	1-9
A	US 5578879 A (G. HEIDELBERG ET AL.), 26 November 1996 (26.11.96), figure 2 -- --------	1-9

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

02/11/99

International application No.
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